

R E M A R K S

Allowable Subject Matter - Claims 3, 4, 6, 7, 29-36, 37 (6), and 37 (29)

Claims 29 through 31 and 33 through 36 were said to be allowable over the art of record and conform to all requirements, as presented.

Claims 3, 4, 6, 7, and claim 37 insofar as it depends on claims 6 and 29, were said to be "allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims."

Claim 32 was said to be "allowable if rewritten or amended to overcome the rejection under 35 U.S.C. §112."

Applicants acknowledge with appreciation that the aforesaid claims define allowable subject matter.

In accordance with Examiner's suggestion, claim 3 which previously depended on claim 1 has been rewritten to include all of the limitations of claim 1.

Claim 4 depends on claim 3 and is submitted to be in form for allowance without amendment in that it now depends directly on allowable claim 3.

Claim 6 depended directly on claim 1 and has now been amended to include all of the limitations of claim 1. Therefore, claim 6 is submitted to be in condition for issuance.

Claim 7 depends on claim 6 and is submitted to be in form for allowance without amendment in that it now depends directly on allowable claim 6.

Claim 32 was rejected on the basis of the use of the term "and/or". This has been corrected in the present amendment and issuance of claim 32 is respectfully requested at Examiner's earliest convenience.

Claim 37 has been amended so that it now depends directly and in the alternative from claims 6 or 29. Claim 6 is submitted to be now in form for allowance. Claim 37 also depends on claim 29 and is now allowable since claim 29 was previously indicated allowable.

Issuance of the aforesaid allowable claims is requested at Examiner's earliest convenience along with all of the other remaining claims in the case, which have been amended to conform to all of the requirements set forth in the Office Action.

Rejection of Claims Under 35 U.S.C. §112

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Claims 13, 24, and 32 were rejected under 35 U.S.C. §112 as being indefinite on the basis that the term "and/or" should not be used in claims, and specifically in the context of the passage "plasma formation, and/or vaporization".

By this present amendment, claims 13, 24, and 32 have been amended to further enhance clarity by stating, in accordance with accepted U.S. Patent and Trademark practice, that the breakdown includes changes caused by "one or more of".

On the basis that claims 13, 24, and 32 now conform to accepted form and terminology, Examiner is requested to withdraw this rejection.

Declaration

Examiner's attention is respectfully directed to the attached "Declaration Traversing Grounds of Rejections Under 37 CFR §1.132 of Peter P. Pronko". In his Declaration, Dr. Pronko traverses each and every ground of rejection set forth in the Office Action dated May 15, 1996 based on art under 35 U.S.C. §102 and 35 U.S.C. §103. Dr. Pronko is a noted expert in the field as evidenced by the credentials highlighted in his Declaration and by the attached curriculum vitae. Dr. Pronko received his Ph.D. in physics in 1966 and has been employed in research for about thirty years. Some of Dr. Pronko's honors, awards, and achievements are listed here.

Presidential Internship at Argonne National Lab - Illinois, 1972-1974.

Sabbatical Year at Solid State Division, Oak Ridge National Lab, 1977-1978.

Symposium Co-organizer for Materials Research Society, Spring 1986 Conference.

Served on organizing committee for the initiation of the MRS Journal of Materials Research.

Chairman of the Full Publications Committee for the materials Research Society (MRS, Pittsburgh, PA), 1989-1991.

Member of Long Range Planning Committee for Materials Research Society, 1991.

Chairman IEEE/LEOS Summer Topical Conference on "Advanced Applications of Lasers in Materials and Processing", Keystone, CO, 1996.

Listed in Who's Who in American Midwest, American Men and Women of Science, and Bohmische Physicaliche Gesellshaft.

Dr. Pronko is one of the joint inventors of the present application. During the time of conception and actual reduction to practice of the invention of the present application, Dr. Pronko, was employed by the University of Michigan, Ann Arbor, Michigan, as a Research Scientist for Ultrafast Optics at the University of Michigan's Center for Ultrafast Optical Science. Dr. Pronko has been named as a joint inventor in several patents; is an author or co-author in over 100 publications; and has been a presenter or joint presenter at over 200 conferences. (See curriculum vitae attached to Declaration.)

It is noted that in item 9 of the Office Action at page 5, that Examiner describes the reasons why previously submitted arguments were not deemed to be persuasive. It is respectfully submitted that such alleged lack of perceived persuasion is based upon the fact that in each of the Office Actions, there is displayed a misunderstanding of the invention and the physics involved. The misunderstandings engendered in the Office Action include the foundation for the §102 rejection based upon the ground that "vaporization occurs which is necessary for plasma to be generated". This supposition shows a fundamental misunderstanding of the invention and the physics involved as will be described more particularly hereinbelow. Further, statements in

the Office Action that "previously presented arguments regarding gold are not relevant to aluminum", again show a fundamental misunderstanding of the invention and of Miyauchi. This is at least because Miyauchi states that there is a definite relationship between the transformation of laser energy into heat for "aluminum or the like". These key misunderstandings will be dealt with specifically as they pertain to each of the related rejections.

Rejection of Claims Under 35 U.S.C. §102

Claims 1, 5, 8 through 11, 13 through 17, 21 through 28, and 40 were rejected under 35 U.S.C. §102(e) as being anticipated by Miyauchi et al.

Claims 1, 21, and 40 are independent claims. Claims 5, 8 through 11, and 13 through 17 depend directly or indirectly on claim 1; and claims 22 through 28 depend directly or indirectly on claim 21.

In the Office Action, the basis of the rejection is stated as, "Miyauchi discloses laser heating of Aluminum of cutting at less than one nanosecond which is less than the threshold of fluence for Aluminum." The Office Action makes the supposition that such cutting is at less than the threshold fluence for aluminum on the basis of Herziger, U.S. Patent No. 4,839,493, saying that Herziger "shows that plasma does not occur until the workpiece is at or above its evaporation temperature." This supposition is incorrect. (See Declaration at items 4 through 6.)

In referencing Herziger, the Office Action states that the plasma does not form until the workpiece is at or above the evaporation temperature for the laser parameters as described in that reference. Based on this premise, the Office Action states

that Miyauchi must be operating at a pulse duration that is less than the pulse width at which there is a change in slope of the threshold fluence versus pulse width curve. (See Declaration at item 5.) However, the Examiner's interpretation of Miyauchi, based on data referenced in Herziger, is simply incorrect. This incorrect interpretation of Miyauchi based on Herziger cannot form a legal basis for rejecting claims to the present invention. It is evident that Examiner is assuming the only way to make a plasma is by heating a material to a temperature above its formation evaporation temperature. This assumption coincides with conventional thinking as per Miyauchi and Herziger. The present invention teaches a surprisingly effective new approach where plasma forms below the melting or evaporation temperature. (See Declaration at item 6.)

As Dr. Pronko explains in his Declaration, in the present invention, plasmas are formed by exposing material to very intense electric fields. This is, in fact, the preferred way to form a plasma as taught by the present invention. That is, by using the intense electric field of the laser pulse. The present invention teaches laser induced breakdown (LIB) which is defined in the patent application, and is dielectric breakdown and plasma formation resulting from multiphoton ionization, or avalanche ionization, or barrier tunneling ionization, or spontaneous auto-ionization, or various combinations of these. The cited art does not remotely suggest LIB. In the short pulse laser-matter interaction of the invention, laser energy absorbed by electrons raises the electron temperature to a very high value in a very short time, forming a plasma, while the lattice temperature remains relatively cold, below the melting or evaporation temperature. (See Declaration at item 7.)

In contrast to the applied art, the method of claims 1, 21, and 40 defines "breakdown" which is laser induced breakdown "LIB" of the material. The present invention as defined in claims 1, 21, and 40 relies upon the production of a spontaneous plasma formed by LIB to effect the ablation, with the result that thermal effects are virtually eliminated, for the first time, by operating near the threshold defined only by the invention. The present invention deviates completely from the $1/t^4$ behavior exemplified by Miyauchi. The process of the invention relies upon operating below the critical point defined by the present invention's "distinct and abrupt change of slope" in the damage fluence versus pulse width threshold curve where the onset of plasma induced breakdown is found to occur. The present invention defines LIB, the onset of which only occurs in the region of distinct change in slope defined in claims 1, 21, and 40 avoids thermal based ($1/t^4$) behavior entirely.

In contrast, Miyauchi relies on thermal ablation process; Miyauchi does not avoid thermal diffusion effects; and Miyauchi cannot effectively minimize collateral damage.

Note particularly that claim 40 has been amended to define "LIB of a material by plasma formation with a pulsed laser beam" with the result that once said beam is focused to a point at or beneath the surface of the material, it induces "breakdown by plasma formation in the material."

It is abundantly evident that Miyauchi does not anticipate claims 1, 21, and 40. Particularly, Miyauchi does not anticipate claim 40 as amended to further define breakdown (LIB) by plasma formation in the material.

Moreover, Miyauchi does not operate in the range of short pulses using laser pulse width in the region where the onset of plasma induced breakdown occurs. It bears repeating that in the present invention, the electric field causes a dielectric breakdown of the material and plasma formation resulting from multiphoton ionization, or avalanche ionization, or barrier tunneling ionization, or spontaneous auto-ionization, or various combinations of these. The presence of this plasma, once formed, is to provide a medium which can undergo a certain amount of hydrodynamic expansion thereby providing an ablative source, or it may also act as a heating source (prior to and/or during expansion) that can cause the temperature of the surrounding material from which it was formed to be increased so that the evaporation occurs AFTER THE PLASMA WAS FORMED. This reverses the logic of the applied art and of the Examiner and, therefore, of necessity reverses the basis for rejection stated in the Office Action. (See Declaration at item 8.)

Further, all of the patents the Examiner references are for long pulse durations and conditions not relevant to the method of the invention. The conditions of the cited art cannot produce LIB (laser induced breakdown) defined in the independent claims. The cited art does not remotely suggest LIB. (See Declaration at item 9.)

The Office Action states that somehow the pulse width of Miyauchi must be in the same range as that defined by the independent claims because Miyauchi is laser heating aluminum and, therefore, somehow Miyauchi must be using pulses for its power level that are within the present invention's defined region. However, Miyauchi misses the region of the invention based on the damage fluence curve characterized in the independent claims. The invention, based on the damage fluence curve, defines the point at

which a transition from thermally controlled processes give way to plasma controlled effects, LIB, laser induced breakdown.

In contrast, Miyauchi has completely missed the point and operates in the regime of thermally controlled processes. (See Declaration at items 9 through 14.)

Miyauchi simply does not achieve LIB. This is because the method of the Miyauchi patent is directly opposite to the method of the present invention. This is because Miyauchi relies exclusively on the concept of the $1/t^2$ dependence of a underlying thermal threshold fluence for melting or evaporation to achieve ablation effect. This means that, by definition, Miyauchi is operating in the region of a damage fluence curve that is completely different from the defined "abrupt and distinct change in slope region" of the present invention.

In contrast to Examiner's interpretation, Col. 2 lines 30-40 of Miyauchi clearly states the square root relationship between power (intensity) and pulse width, with NO LIMIT on pulse width ranges, and no suggestion of "LIB" and "plasma formation". These terms are not mentioned anywhere in Miyauchi. Miyauchi did not reach LIB at all. Further, although Miyauchi states a laser pulse of "1 nanosecond or less", in Col. 3 at line 35, he specifies "100 to 300 picoseconds". This is well outside the femtosecond range of the present invention.

Note here that Miyauchi's 100 to 300 picoseconds at Col 2 at lines 59-62 is for material "made of aluminum or the like." Clearly, Miyauchi's range was meant to be exemplary for a metal, evidencing Miyauchi's inability to achieve LIB as defined by the present invention. (See Declaration at item 14.)

Miyauchi is in accord with the conventional thinking that for a metal it is sufficient to operate within the 100 to 300 picosecond regime to attempt to avoid thermal effects.

In contrast, the invention, for the first time, defines a femtosecond region, as an upper limit, required to achieve LIB mechanism. Therefore, Miyauchi cannot achieve the LIB mechanism in the pulse width picosecond regime Miyauchi defines. (See Declaration at items 14 through 16.)

In summary, the present invention contradicts Miyauchi and conventional thinking by new data. This new data demonstrates that for a metal, such as Al and Au, LIB mechanism as defined in the items above, and in the present invention, occurs at a laser pulse well outside Miyauchi's 100 to 300 picoseconds. Miyauchi never suggested the femtosecond range of the present invention necessary to achieve LIB mechanism; and Miyauchi never identified the present invention's "change of slope" characterization. (See Declaration at item 15.)

The present invention relies upon the production of a spontaneous plasma formed by LIB to effect the ablation, and recognizes that thermal effects are virtually eliminated from the process when operating near the threshold. Therefore, the present invention deviates completely from Miyauchi's $1/t^4$ behavior. The novel plasma process occurs when one operates below the critical point defined by the present invention's "distinct change of slope" in the damage fluence versus pulse width threshold curve. The present invention, for the first time, specifically teaches that one should avoid doing what Miyauchi et al teach. That is to say, the present invention avoids thermal based ($1/t^4$) behavior entirely. In contrast, Miyauchi relies on such thermal ablation

process. (See Miyauchi at Col. 2 at lines 30-45.) (See Declaration at item 16.)

By operating in accordance with conventional teaching, Miyauchi does not avoid thermal diffusion effects and disruptive energy delivered into the bulk material surrounding the area desired to be ablated. Therefore, Miyauchi cannot minimize collateral damage. This is accomplished, for the first time, only by the present invention. Miyauchi et al admit that their method cannot effectively minimize collateral damage. Based on the teaching of the present invention, we now know why Miyauchi has failed in this regard. Miyauchi et al have completely misunderstood and misdefined the pulse duration at which damaging, collateral thermal effects are significant. Referring to Col. 2 beginning at line 59, it states that "It takes about 1 nanosecond for the laser energy to be transformed into heat within the interconnection pattern made of aluminum or the like." The implication here is that at 100 to 300 picoseconds no significant thermal processes are occurring. This is simply wrong. The present invention shows that for metals, such as aluminum, gold, and the like, the pulse duration must be shorter than about 10 picoseconds for thermal effects to be significantly minimized. Therefore, for the first time, we now understand why Miyauchi has not been able to avoid collateral damage. That is because Miyauchi teaches to operate in the $1/t^2$ regime at 100 to 300 picoseconds as stated in their discussion at Col. 2 at lines 40-45. (See Declaration at items 17 through 20.)

In view of contrary opinion of the expert, Examiner is requested to show proof, under 37 CFR 1.107(b), that Miyauchi is operating in a range which causes LIB and proof to show where in Miyauchi there is a teaching as to the change in slope and pulse width necessary to cause the LIB. In view of opinion of expert

demonstrating that he does not agree with the assumptions and positions taken by the Examiner.

In view of the above, the rejection of independent claims 1, 21, and 40 and dependent claims 5, 8 through 11, 13 through 17, and 22 through 28 is unsupportable under 35 U.S.C. §102. The present invention simply does not "read" on Miyauchi. This is at least for the following reasons:

1. The Examiner's interpretation of Miyauchi based on data referenced in Herziger is simply incorrect in rejecting claims to the present invention.
2. Examiner is assuming that the only way to make a plasma is by heating the material to a temperature above its formation evaporation temperature. This assumption coincides with conventional thinking as per Miyauchi and Herziger.
3. The present invention teaches a surprisingly effective new approach where plasma forms below the melting or evaporation temperature. In the present invention, plasmas are formed by exposing material to very intense electrical fields. This is, in fact, the preferred way to form a plasma as taught by the present invention. That is, by using the intense electric field of the laser pulse. The present invention teaches laser induced breakdown (LIB) which is defined in the patent application, and is dielectric breakdown and plasma formation resulting from multiphoton ionization, or avalanche ionization, or barrier tunneling ionization, or

spontaneous auto-ionization, or various combinations of these.

4. The cited art does not remotely suggest LIB.
5. Miyauchi does not avoid thermal diffusion effects and Miyauchi does not avoid collateral damage because Miyauchi operates in the $1/t^2$ regime at 100 to 300 picoseconds (Col. 2 at lines 40-45).
6. By the method of the invention, it is clearly shown that for metal the pulse widths in the femtosecond range are required to cause damage by laser induced breakdown (LIB).
7. Miyauchi is directly opposite to the method of the present invention, since Miyauchi's mechanism depends on $1/t^2$ dependence of a thermal fluence for melting or evaporation to achieve ablation effect.
8. By the mechanism of the present invention, the electric field causes a dielectric breakdown of the material and plasma formation results from multiphoton ionization, or avalanche ionization, or barrier tunneling ionization, or spontaneous auto-ionization, or various combinations of these.
9. The presence of this plasma can cause the temperature of surrounding material from which it was formed to be increased so that evaporation occurs after the plasma is formed. This is contrary to the applied art and contrary to the assumptions

made by Examiner in the Office Action. (See Declaration at items 4 through 20.)

Independent claims 1 and 21 and dependent claims 8 through 11, 13 through 17, and 22 through 28 were rejected on the basis of Zinck. Again, it is respectfully submitted that the Office Action shows a significant misinterpretation of Zinck.

The method defined in Zinck is for processing Cd/Te semiconductor material. The Office Action states "Zinck et al in U.S. Patent No. 5,454,092 performs ablation below the threshold fluence; consequently, Zinck et al must be using pulses for its power level that are less than the pulse width at which there is a change in slope of the threshold fluence versus pulse width." (See Declaration at item 22.)

Importantly, according to Dr. Pronko, Zinck et al misuses the term "ablation". According to Dr. Pronko, Zinck et al are not performing an ablation procedure at all. Clearly, according to Dr. Pronko, Zinck et al are not performing any operation remotely associated with LIB. (See Declaration at item 23.)

According to Dr. Pronko, Zinck is only concerned about energy fluence levels related to preferential surface annealing. This is totally unrelated to the present invention which defines preferred threshold fluence for LIB mechanism. (See Declaration at items 23 through 27.)

The rejection based on Zinck is so clearly inappropriate and really incomprehensible that it is difficult to know where to begin to discuss it. Zinck merely contains a curve that shows a relationship between Cd/Te ratio obtained by thermal anneal versus laser fluence. This curve in Zinck shows relationship between

stoichiometry/thermal anneal versus laser fluence. It is abundantly clear, even to those unskilled in the art, that such a curve has absolutely no relationship whatsoever to a curve of a damage fluence versus pulse width. Clearly, the axes of Zinck have absolutely no relationship to the parameters shown on the axes of the curves of this present invention. In further support of the inappropriateness of the rejection on Zinck, it is completely clear that the power levels at which Zinck is operating are so extremely low, that melting of the surface is avoided. Therefore, Zinck does not even reach the power levels of Miyauchi and in turn, Miyauchi never reaches laser induced breakdown ablation. (See Declaration at items 22 through 29.)

Zinck is restricted to nanosecond laser pulses exclusively. Clearly, nanosecond laser pulses are well outside the femtosecond range defined by the present invention for metals.

In view of contrary opinion of the expert, Examiner is requested to show proof, under 37 CFR 1.107(b), to support Examiner's supposition that Zinck's fluence relationship versus stoichiometry is similar to Applicants' "threshold fluence versus pulse width" and to support the assumption that Zinck must be using pulses for his power level that are less than the pulse width at which there is the change in slope of threshold fluence versus pulse width. This, in view of opinion of expert demonstrating that he does not agree with the assumptions and positions taken by Examiner.

For these and all of the reasons set forth in the Declaration at items 21 through 29, it is evident that Zinck does not "read on" Applicants' independent claims 1 and 21. For these same reasons, Zinck does not read on any of dependent claims 8 through 11, 13 through 17, and 22 through 28.

Rejection of Claims Under 35 U.S.C. §103

Claims 18, 20, and 38 were rejected under 35 U.S.C. §103 as being unpatentable over Miyauchi et al in view of Kunz et al on the basis that Kunz et al teaches a flexible diaphragm to change the transverse mode of a laser beam.

Claims 18, 20, and 38 each depend from claim 1. It is respectfully submitted that claims 18, 20, and 38 are patentable for the reasons given hereinabove with respect to claim 1 and further on the basis that Kunz does not even mention any operating conditions; and does not have anything to do with LIB. It is inappropriate to attempt to combine Kunz with Miyauchi to try to arrive at the invention because Kunz does not define the key elements of the present invention which are missing from Miyauchi. (See Declaration at items 29 and 30.)

Claims 20 and 38 were rejected under 35 U.S.C. §103 as being unpatentable over Miyauchi et al in view of Von Allmen et al, on the basis that Von Allmen teaches ablating with a laser beam of a particular mode.

Claims 20 and 38 each depend from claim 1 and are submitted to be patentable for the reasons given in connection with claim 1 and further because Von Allmen et al merely involved the use of nanosecond pulses to lase liquid zones created in a melt region that was previously exposed to a laser. Von Allmen et al is only interested in the trailing edges of the pulses should drop well below the material removal point at a time of 100 nanoseconds. Accordingly, Von Allmen et al has a total pulse duration of about 5 microseconds. It is clear that the operating conditions of Von Allmen are completely outside the range of very short pulse duration, i.e. femtoseconds, and do not remotely suggest pulse

duration necessary to operate at the onset of LIB type breakdown. It is inappropriate to attempt to find in Von Allmen key elements of the invention which are not found in Miyauchi because such elements are missing in both Von Allmen and Miyauchi. Therefore, they cannot be combined to try to arrive at the invention. (See Declaration at items 31 and 32.)

Claims 2, 12, 19, and 37 insofar as it depends on claims 1, 2, 5, and 21, and claim 29 were rejected under 35 U.S.C. §103 as being unpatentable over Miyauchi et al with official notice taken that chirp pulse amplification is known in the art. As stated in the Declaration at items 33 and 34, Dr. Pronko does not agree with Examiner's supposition that those skilled in the art would have been able to adapt Miyauchi and arrive at the femtosecond pulse duration. Dr. Pronko states that there is simply no teaching in Miyauchi to create short, high power pulses as in the invention, use femtoseconds to ablate metal, and to ablate by LIB mechanism in small areas while essentially completely avoiding collateral damages in the present invention. As stated earlier, Miyauchi does not remotely suggest the critical LIB mechanism; does not remotely suggest the threshold where the mechanism of thermal effects gives way to plasma controlled effects induced by LIB; and does not essentially avoid collateral damage as made possible by the very critical relationship which defines the "distinct change of slope" region in the damage fluence versus laser pulse width threshold curve. Since Miyauchi completely misses the critical key features of the invention, there is no motivation for Miyauchi to combine chirped pulse amplification with the teachings of the independent claims.

Examiner is using hindsight and taking the advantage of knowing what the inventors have done to suppose that the invention should be done. (See Declaration at items 33 and 34.)

Therefore, claims 2, 12, 19, and 37 insofar as it depends on claims 1, 2, 5, and 21, and claim 29 are submitted to be patentable for these reasons and for the reasons given in connection with claims 1 and 21 from which such claims directly or indirectly depend.

It is noted that in item 9 of the Office Action, Examiner summarizes many of the misunderstandings engendered in the previous Office Action items that form the foundation for the rejection including "that vaporization occurs which is necessary for a plasma to be generated."

This supposition shows a fundamental misunderstanding of the invention and the physics involved. Further, the statement that the previously presented arguments regarding gold are not relevant to aluminum, again show a fundamental misunderstanding of the invention, and of Miyauchi.

Miyauchi states that there is a relationship between the transformation of laser energy into heat for "aluminum or the like". Therefore, Examiner's summary dismissal of the previously submitted arguments is inappropriate. (See Declaration at item 35.)

As to each and every one of the rejections under 35 U.S.C. §103, Examiner is requested, by affidavit, to provide a basis upon which to support the rejection of the claims since opinion of expert demonstrates there is absolutely no support in Miyauchi for key features of the invention as defined in independent claims 1, 21, and 40, including but not limited to: (1) Miyauchi does not remotely suggest the critical LIB mechanism; (2) does not remotely suggest threshold where the mechanism of thermal effects gives way to plasma controlled effects induced by LIB; and

(3) does not essentially avoid collateral damages made possible by the very critical relationship which defines the "distinct change of slope" region in the damage fluence versus laser pulse width threshold curve.

In summary, it is respectfully submitted that all of the pending claims 1 through 40 and newly presented claims 41 through 45 are patentable and distinguish clearly over the applied art. In the event that this amendment does not result in allowance and pass to issuance of all pending claims, the undersigned respectfully requests benefit of telephone interview with Examiner and/or Examiner's supervisor at a time convenient for Examiner.

Respectfully submitted,

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Attachment: Declaration of Peter P. Pronko